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INFLUENCE OF VINE KILLING AND 2,4-D ON YIELD, SPECIFIC GRAVITY, AND VASCULAR DISCOLORATION OF POTATOES[1]

C. E. Peterson[2] and Aral B. Gwinn[3]

Killing potato vines prior to harvest is a generally accepted practice in the muck land area of Iowa. From the standpoint of Iowa growers the chief objective of vine killing is to eliminate vines as an obstacle to harvesting. With the increasing use of late maturing varieties and the natural desire to extend the harvest period by efficient vine removal, it is necessary to understand the influence of various vine killing practices on yield and quality of the crop. Since it is generally understood that early killing results in losses in yield and cooking quality it would be useful to establish the extent of these losses as influenced by time and method of killing, environmental conditions, and variety. If the effect of vine killing is understood, the grower can decide whether the advantages to be gained are greater than the expected losses.

Most of the work on vine killing has been reported during the past five years. These studies have generally been concerned with the efficiency of killing methods and their effects on vascular discoloration of tubers and have not dealt extensively with the influence of vine killing on yields and cooking quality. Kunkel *et al.* (12) reported that chemical vine killers applied two weeks before the first killing frost did not significantly reduce total yields of Red McClure potatoes in Colorado but that specific gravity of tubers was reduced by vine killing. McGoldrick (16) reported that yields were affected adversely by vine killing and that tubers were found to increase appreciably in size even after vines were showing symptoms of natural senescence. It was also observed that the destruction of green vines resulted in lower specific gravity of tubers and that the more rapid and complete the kill the greater was the decrease in density.

A number of investigators (2, 4, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 25, 26, 27) reported increased vascular discoloration in potato tubers following vine killing. More severe vascular discoloration with fast compared with slow-killing chemicals was reported by Hoyman (10), Eastman (6), Callbeck (2), McLachlan and Richardson (14), Rich (25, 26) and Cunningham *et al.* (4). Prince *et al.* (22) reported no correlation between rate of kill and amount of discoloration. Wilson *et al.* (30) observed no vascular discoloration following the use of fast killing chemicals in Great Britain. In Oregon, Otis (19) observed no discoloration resulting from the use of some of the same chemicals that produced the discoloration described by Steinbauer (27) in Maine and by Hoyman (10) in North Dakota. Meadows (15) was able to produce vascular discoloration by vine killing in only one of four locations in New York. At that location discoloration was observed in both 1948 and 1949 despite growing conditions described as ideal in 1948 and as hot and dry in 1949.

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[2]Horticulturist, U. S. Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Ames, Iowa.

[3]Formerly Graduate Assistant, Horticulture Section, Iowa Agricultural Experiment Station, Ames, Iowa.

Hoyman (10), Gwinn (9) and Meadows (15) observed vascular discoloration following mechanical as well as chemical vine killing whereas Eastman (6) and Rich (25, 26) reported no increase in discoloration resulting from mechanical vine killing.

Varietal differences in development of vascular discoloration following vine killing were reported by Prince *et al.* (22), Meadows (15), Gwinn (9) and Cunningham *et al.* (4).

In contrast with results reported by Hoyman (10) and Gwinn (9), who found more discoloration following early killing, Callbeck (2), Eastman (6) and McGoldrick (16) reported increased discoloration with late killing. Cunningham *et al.* (4) reported that discoloration produced by vine killing tended to increase with age until the plants were maturing rapidly, after which time there was a decline in the amount of discoloration.

Kunkel *et al.* (13) found more discoloration if soil moisture content was low when vines were killed. Hoyman (11) also reported that tubers grown under conditions of limited soil moisture were more subject to vascular discoloration following vine killing. Murphy (18) described a vascular necrosis of potato tubers following severe drought conditions with no artificial vine destruction.

The tolerance of the potato to 2,4-D has been widely reported and the possibilities of using 2,4-D for weed control in potatoes were studied by Thompson and Shuel (28), Warren and Hernandez (29), Bradley and Ellis (1), and Danielson (5). In most of these studies effective control of broad-leaved weeds with 2,4-D was achieved and differences in response of potato varieties were observed. Intensification of tuber color in red varieties resulting from applications of 2,4-D was reported by Fults and Schaal (8) and by Ellis (7).

The possibility of using 2,4-D on potatoes to hasten vine maturity and accomplish the purposes of vine killing was suggested by Peterson and Haber (20), who observed that certain 2,4-D treatments on Sebago potatoes in midsummer resulted in earlier vine maturity without a significant reduction in yield. Later results (21) demonstrated that response to 2,4-D was influenced by such factors as variety, chemical formulation, weather conditions and time or rate of application.

Prince and Blood (23) reported an increase in specific gravity of tubers from vines sprayed in the full bloom stage with one-half pint per acre of 40 per cent 2,4-D butyl ester. Of six varieties only Sebago failed to show an increase in specific gravity following treatment. Smith *et al.* (24) reported that the sodium salt of 2,4-D (10 ppm) applied at rates varying from 55 to 110 gallons per acre produced no visible effect on vine growth and did not affect yields or starch content of tubers.

Materials and Methods

Vine killing trials were conducted with potatoes grown in muck soil at Clear Lake, Iowa, in 1949 and 1950. The same varieties and treatments were used both years in a randomized split-plot design with four replications. A block consisted of six plots, each of which contained four varieties (Cobbler, Kennebec, Yampa and Sebago). The varieties were planted in 25-hill rows or sub-plots randomized within the main plots. Guard rows were planted so that sprayer-wheel damage to the plots could be avoided.

Killing treatments applied to the main plots were as follows: (1)

early mechanical, (2) late mechanical, (3) early chemical, and (4) late chemical. Other treatments were a 2,4-D spray applied in midsummer and check plots allowed to grow until killed by frost. The sodium salt of 2,4-D was used in a solution giving 2 pounds of the acid equivalent per hundred gallons and application was at approximately 100 gallons per acre. The chemical vine killer was DNOSBP[4] mixed at the rate of 2 pints plus three gallons of diesel fuel in 100 gallons of water. Application was at the rate of approximately 100 gallons per acre. Mechanical killing was accomplished by cutting the vines about four inches above the ground on the dates the chemicals were applied.

An effort was made to follow the same procedures in the two years. Table 1 shows how the dates of various operations and treatments compared in 1949 and 1950. Details of procedure and results for 1949 have been reported elsewhere by Gwinn (9).

Specific gravity determinations were made within a week after harvest by the saline solution method described by Clark *et al.* (3). Four 30-tuber samples were used for determining the mean specific gravity of tubers from each treatment.

The same samples were examined for vascular discoloration after about three months' storage at 40° to 50°F. A slice ¼ to ⅜ of an inch thick was cut from the stem end and tubers were classified as having severe, moderate, slight or no discoloration.

The two years during which these experiments were performed provided widely different climatic conditions. It is unfortunate that data were not secured for a season which would represent a closer approach to normal. However, having two extreme seasons, one cool with ample moisture and one rather hot and dry during most of the growing season, provides an indication of the influence of climatic factors on the response of potatoes to vine killing. Climatological data for the summer months of 1949 and 1950 are summarized in table 2.

Experimental Results

Relation of Yields and Treatment

In table 3 mean yields are recorded for each year separately and

TABLE 1.—*Pertinent dates for vine killing experiments, 1949 and 1950, Clear Lake, Iowa.*

Operation or Occurrence	1949	1950
Planting	May 5	May 23
2,4-D spraying	July 12	July 20
Early vine killing	August 26	August 21
Late vine killing	September 9	September 2
Frost occurrence	September 24	September 23
Harvesting	September 25	September 25
Observation of tuber discoloration	January 6	December 26

[4]Dinitro ortho secondary butyl phenol supplied in experimental quantities by Standard Agricultural Chemicals, Inc., as Sinox General.

TABLE 2.—*Mean temperatures and rainfall, 1949 and 1950*[1]

Month	Temperatures in Degrees Fahrenheit								Rainfall in Inches			
	Mean Maximum		Mean Minimum		Mean Monthly							
	1949	1950	1949	1950	1949	Dep.[2]	1950	Dep.[2]	1949	Dep.[2]	1950	Dep.[2]
June	82.6	77.1	59.2	54.0	70.9	+3.3	65.6	—0.0	7.61	+2.95	4.73	+ .07
July	86.1	79.4	62.5	55.5	74.3	+1.3	67.5	—5.5	5.02	+1.55	5.70	+2.23
August	84.0	77.1	59.5	53.8	71.8	+1.6	65.5	—4.7	1.06	—3.10	2.19	—1.97
Sept.	70.1	72.6	44.0	42.3	57.1	—4.8	60.0	—1.9	3.76	—0.08	2.30	—1.54

[1]Data from Mason City, Iowa, Airport approximately three miles from the potato plots.
[2]Departure from normal.

for the two years combined. In the analysis of variance of the combined data the interaction treatment x years was not significant, indicating that the treatment effects did not differ greatly during the two years. Likewise, the three-factor interaction, variety x treatment x years, was not significant, indicating that years did not cause any marked change in the variety x treatment interaction. From the highly significant variety x treatment interaction in each year separately and in the combined analysis for two years, it is evident that varieties responded differently to the treatments. The differences become apparent when individual means are examined.

Yields of Cobbler were not affected significantly by any of the killing treatments whereas the later varieties, Kennebec and Sebago showed substantial reduction in yield particularly with early killing. In 1949 Yampa yields were reduced significantly by early but not by late killing. In 1950 a significant reduction in yield resulted from late as well as from early killing of Yampa. An example of the extent of losses that may result from vine killing was observed in the case of Kennebec in 1950 as shown in table 3. Compared with check plots allowed to grow until frost on September 23, yields of this variety were reduced 270 bushels per acre by mechanical killing on August 21 and 133 bushels by the same method of killing on September 2.

For the two-year period, early killing by either method resulted in yields of Kennebec, Yampa and Sebago that were significantly lower than those of Cobbler, the check variety, killed on the same dates (Table 3). Late mechanical killing resulted in yields of Kennebec and Yampa that were not significantly below those of Cobbler. When allowed to grow until frost, Kennebec produced a significantly higher yield than Cobbler.

In 1949 there was no significant reduction in yield of any of the four varieties sprayed on July 12 with the sodium salt of 2,4-D. Application of the same treatment on July 20, 1950 resulted in a significant reduction in yield of Cobbler. None of the other varieties showed a significant response. Combined data for two years show no significant influence of the 2,4-D spray on yields of any of the four varieties.

Response of Plants to 2,4-D

The immediate reactions of the varieties to 2,4-D were widely

TABLE 3.—*Yields of potatoes from vine killing and 2,4-D treatments, Clear Lake, Iowa.*

Variety and Year	Check	2,4-D	Chemical Kill		Mechanical Kill		Mean
			Early	Late	Early	Late	
1949:	Bus.	Bus.	Bus.	Bus.	Bus.	Bus.	Bus.
Cobbler	364	421	346	372	376	349	371
Kennebec	416	373	246	317	272	354	330
Yampa	275	233	157	296	168	294	237
Sebago	426	468	277	325	208	339	341
Mean	370	374	257	328	256	334	
1950:							
Cobbler	499	425	456	515	433	493	470
Kennebec	588	599	397	417	318	455	462
Yampa	576	540	396	492	396	496	483
Sebago	449	500	365	371	281	328	382
Mean	528	516	403	449	357	443	
1949-50:							
Cobbler	431	423	401	443	404	421	420
Kennebec	502	486	321	367	295	404	396
Yampa	425	386	276	394	282	395	360
Sebago	437	484	321	348	282	333	361
Mean	449	445	339	388	306	388	

Least significant difference:	1949		1950		1949-50	
	.05	.01	.05	.01	.05	.01
Between treatment means	48	65	64	89	39	53
Between variety means	38	51	29	38	23	31
Between treatments within variety	93	124	71	94	58	76
Between varieties within treatments	94	125	86	114	63	83

different and they were not the same in both years. In 1949 plants of Cobbler and Yampa showed more intense reaction during the first week after application than did those of Kennebec or Sebago. Seventeen days after spraying, Cobbler showed almost complete recovery and symptoms of injury were difficult to find while Yampa continued to show rather intense and persistent symptoms. There was very little new terminal growth in Yampa after spray application. Only the young terminal leaflets of Kennebec and Sebago developed severe symptoms of 2,4-D injury. Both the mature leaves and the new growth occurring after spray application were normal in these varieties, but the symptoms persisted in the affected leaves until maturity.

In 1949 Cobbler plots sprayed with 2,4-D on July 12 were approximately 90 per cent dead on August 20, whereas untreated plots reached the same stage of maturity a week later. Kennebec, Yampa, and Sebago vines in the 2,4-D plots were all approaching 90 per cent maturity just before frost on September 24, whereas the untreated vines of these varieties were only 50 to 60 per cent dead, indicating that maturity was 10 to 14 days earlier in these varieties as a result of 2,4-D application. These results confirmed observations made on Kennebec and Sebago at Clear Lake and Crystal Lake, Iowa, (20, 21).

The 1950 experiment failed to produce vine responses to 2,4-D similar to those of the preceding year. Cobbler and Yampa plants showed the most intense response immediately after spraying, but both showed recovery similar to that of Cobbler in 1949. Typical malformations developed in only the young terminal leaves of Yampa. These symptoms persisted in the affected leaves but new growth was normal. The responses of Kennebec and Sebago were also less severe than in 1949, and vine maturity was not hastened to an appreciable degree in any of the varieties.

Relation of Specific Gravity and Treatment

Specific gravity data presented in table 4 are the mean values for samples from each of the four replications. The statistical analyses revealed highly significant differences due to treatments and to varieties in both years. The variety x treatment interaction is significant, exceeding the 5 per cent level of probability in 1949 and the 1 per cent level in 1950. In the combined analysis the interactions variety x years and variety x treatment are both highly significant. In these significant interactions there is evidence that varieties did not respond alike to the different conditions in the two seasons and that they differed in response to the various treatments.

In 1949 Cobbler had a specific gravity reading of 1.069 when allowed to grow until frost. Significantly lower readings, 1.065 and 1.064, resulted from vine killing on August 26. Tubers from Cobbler plots killed mechanically on September 9 were also significantly lower than those from check plots of that variety. Since the yield data indicated that Cobbler made no significant gains after the first vine killing, it is apparent that the tubers continued to increase in starch content after they had stopped making significant gains in size.

Kennebec showed small but statistically significant gains in specific gravity after early killing in 1949. Although these differences (1.063 for early killing compared with 1.066 for the check) can be measured with

TABLE 4.—*Specific gravity of potato tubers from vine killing and 2,4-D treatments. Clear Lake, Iowa, 1949 and 1950.*

Variety and Year	Check	2,4-D	Chemical Kill		Mechanical Kill		Mean
			Early	Late	Early	Late	
1949:							
Cobbler	1.069	1.065	1.065	1.068	1.064	1.065	1.066
Kennebec	1.066	1.067	1.063	1.064	1.063	1.067	1.065
Yampa	1.068	1.069	1.065	1.069	1.063	1.068	1.067
Sebago	1.073	1.070	1.064	1.068	1.065	1.068	1.068
Mean	1.069	1.067	1.064	1.067	1.064	1.067	
1950:							
Cobbler	1.074	1.072	1.070	1.073	1.071	1.072	1.072
Kennebec	1.078	1.079	1.069	1.073	1.066	1.072	1.073
Yampa	1.078	1.077	1.071	1.076	1.071	1.074	1.075
Sebago	1.074	1.075	1.067	1.069	1.061	1.066	1.069
Mean	1.076	1.076	1.069	1.073	1.067	1.071	

Least significant difference:	1949		1950	
	.05	.01	.05	.01
Between treatment means	.001	.002	.002	.003
Between variety means	.001	.002	.001	.002
Between treatments within varieties	.003	......	.003	.004
Between varieties within treatments	.003	......	.003	.004

sufficient accuracy to be statistically significant, it is doubtful whether they are of any practical significance. However, in 1950 the lower specific gravity (1.069 and 1.066) resulting from early killing compared with the specific gravity of tubers from the check plots (1.078) are of sufficient magnitude to be of practical importance since such differences can be detected rather easily in the quality of the cooked product.

A comparison of mean tuber density of Cobbler with that of the other varieties within treatments reveals some striking differences in the relationship among varieties in the two seasons. In 1949 Kennebec tubers were significantly lower in density (1.066) than Cobbler (1.069) when allowed to grow until killed by frost on September 24. With the same treatment in 1950 the mean specific gravity of Kennebec was 1.078 and of Cobbler 1.074. Statistically these differences are significant, but their

practical significance is doubtful. Yampa and Cobbler showed a similar change in the two years with no difference in 1949 and a significantly higher reading for Yampa in 1950. Sebago was significantly higher than Cobbler in the check plots in 1949 but not different in 1950.

The specific gravity of Cobbler and Sebago was reduced significantly by the 2,4-D treatment in 1949. The following year 2,4-D produced no appreciable change in density of any variety compared with that of the untreated check.

Relation of Vascular Discoloration and Treatment

The incidence of vascular discoloration in tubers from vine killing plots is recorded in table 5. In 1949 there were highly significant differences between treatment means when all varieties were included, but no significant interaction was found between varieties and treatments, indicating that all four varieties responded similarly to the treatments used. Both chemical and mechanical killing caused a highly significant increase in the number of discolored tubers. Compared with the check plots, the increase in discoloration was slightly greater in tuber samples from the plots killed mechanically on August 26 than in those from plots killed by either method on September 9. In contrast, the 1950 data show no significant treatment differences. However, for both years there were highly significant differences between variety means averaged for all the treatments. The performance of Yampa was consistent in this respect, being lower than the Cobbler check by highly significant differences both years. In 1949 Kennebec also had a significantly lower incidence of discolored tubers than did Cobbler.

In the combined analysis the differences due to years, treatments and varieties are highly significant. The highly significant treatment x years interaction is accounted for by the fact that killing treatments produced significant increases in discoloration in 1949 but not in 1950. The variety x years interaction is also highly significant but the three factor interaction, variety x treatment x years, is not significant.

The index values for severity of discoloration presented in table 6 were computed by giving numerical values of 1, 2 and 3, respectively, for slightly, moderately and severely discolored tubers. By adding the products of the number of tubers in each class multiplied by the numerical value for the class and then dividing by the total number of discolored tubers, the index values shown in table 6 were obtained.

It is evident from the data in table 6 that discoloration in 1949 was much more severe than in 1950. This difference is proportionately much greater than is the case with the number of discolored tubers as you observed in table 5. In other words, there was relatively little decrease in incidence of discoloration in 1950 compared with 1949, but the tubers were less severely affected.

Discussion

The effect that vine killing will have on yield and quality of a potato crop depends on variety, time and method of killing, and climatic factors. The results of two years' trials indicate that vine killing should be delayed as long as possible in order to obtain maximum yields of late varieties. In Iowa despite rather early killing, some late varieties produced

TABLE 5.—*Incidence of vascular discoloration in tubers from vine killing and 2,4-D treatments, Clear Lake, Iowa, 1949 and 1950.*

Variety and Year	Check	2,4-D	Chemical Kill		Mechanical Kill		Mean
			Early	Late	Early	Late	
1949:							
Cobbler	13.7[1]	13.5	19.5	18.5	19.5	18.2	14.9
Kennebec	8.2	7.2	10.0	10.5	15.5	11.0	10.4
Yampa	6.7	7.2	10.0	12.0	11.7	10.5	8.6
Sebago	8.0	10.0	16.2	15.5	19.2	15.5	14.1
Mean	9.2	9.5	14.4	14.1	16.5	13.8	
1950:							
Cobbler	11.5	13.7	12.2	10.7	15.0	12.5	12.6
Kennebec	11.2	12.0	11.7	10.5	13.7	11.7	11.8
Yampa	10.2	7.2	7.5	6.5	7.2	6.7	7.6
Sebago	13.0	11.0	14.2	12.2	11.2	10.5	12.0
Mean	11.5	11.0	11.4	10.0	11.8	10.4	

[1] Number of tubers in 30-tuber samples showing some degree of discoloration. Mean of four replications.

	1949		1950	
Least significant difference:	.05	.01	.05	.01
Between treatment means	1.1	1.6	....	....
Between variety means	0.9	1.2	1.3	1.8

yields as high as Cobbler, which normally has produced its maximum yield by about September 1. An example of this may be noted in comparing Kennebec and Cobbler (Table 3). The yield data from mechanically killed plots in 1949 showed Kennebec to be 104 bushels below Cobbler on August 26. Two weeks later Kennebec yields were equal to those of Cobbler. In 1950 Kennebec yields were 115 bushels below Cobbler on the first date of kill (August 21) and only 38 bushels below Cobbler on the second date (September 2). On the latter date Kennebec was still 133 bushels per acre below its eventual yield of 588 bushels from plots killed by frost September 23. It is evident that under these conditions, only a few days' delay would result in appreciable gains in yield. The delay that can be achieved in practice will depend upon other considerations such as disease control, preventing development of oversize and rough tubers, and danger from freezing. Nevertheless, the magnitude of yield

increases during the last weeks of the growing season should be appreciated.

These results also emphasize the importance of varieties that mature their maximum crop early or set tubers early and produce a heavy yield before the usual occurrence of frost. The performance of a particular variety in this respect needs to be understood in order to make the most intelligent use of vine killing procedures.

The average date for the first killing frost in the fall at Clear Lake, Iowa, is about September 30. Yields of late varieties like Kennebec and Sebago will increase up to that date. The 1949 data indicate that Yampa was approaching its maximum yield by September 9 whereas the following year Yampa continued to make substantial gains in yield after the second date of kill, September 2. In 1949 it was the lowest yielding of the four varieties, having a yield of 275 bushels from the check plots compared with 364 bushels for Cobbler. The following year Yampa was second in yield, producing 576 bushels per acre compared with 499 bushels for Cobbler. This higher yield was produced in a growing season 19 days shorter than the preceding season. It is evident that Yampa was sensitive to hot, dry conditions prevailing during July and August 1949.

Cobbler did not make significant gains in yield after the first date of killing. Conditions in 1949 favored the early variety because tuberization and growth of tubers had progressed most rapidly during July and early August before drought conditions developed. The later varieties were producing tubers during late August and early September when temperatures were high and rainfall inadequate. In 1950 conditions favored the late varieties because almost ideal conditions for tuber growth persisted up to the first frost.

The important differences in reaction of varieties in the two years were generally higher yields in 1950 with higher specific gravity and less severe vascular discoloration due to vine killing treatments. There was also a less intense reaction in the vines to 2,4-D application and the 2,4-D treatment did not hasten vine maturity as it had in 1949. In 1950 it was also noted that the dinitro spray produced a much slower kill, approximately four days being required to accomplish a complete kill compared with less than one day in 1949.

These responses may be attributed to differences in climatic conditions. The 2,4-D treatment was applied on July 12 in 1949, when the temperature was 87°F. Maximum temperatures were above 90°F. five out of the ten days just preceding July 12, with an average maximum of 90.2°. During the two weeks prior to treatment, total precipitation was 0.1 inch. In 1950 the 2,4-D application was made on July 20, when the temperature was 77°. Average maximum temperature for the preceding ten days was 76.4°, with only three days above 80°. Precipitation during the preceding two weeks totaled 4.9 inches.

Whether temperature, moisture, or a combination of both was responsible for the difference in response to 2,4-D cannot be determined from these data. Despite the more severe vine symptoms and earlier maturity resulting from 2,4-D spray in 1949 there were only slight effects on specific gravity, discoloration of tubers, or yields. Likewise in 1950 there were no changes in tuber density or vascular discoloration due to the 2,4-D treatment and only one case of a significant reduction in yield. The significant decrease in yield of Cobbler after 2,4-D treatment in 1950

TABLE 6.—*Severity of discoloration in tubers from vine killing and 2,4-D treatments, Clear Lake, Iowa, 1949 and 1950.*

Variety and Year	Check	2,4-D	Chemical Kill		Mechanical Kill		Mean
			Early	Late	Early	Late	
1949:							
Cobbler	1.49[1]	1.59	1.56	1.60	1.72	1.57	1.59
Kennebec	1.31	1.28	1.50	1.31	1.21	1.40	1.34
Yampa	1.57	1.24	1.64	1.47	1.26	1.57	1.46
Sebago	1.55	1.33	1.76	1.57	1.63	1.54	1.56
Mean	1.48	1.36	1.60	1.49	1.46	1.52	
1950:							
Cobbler	1.00	1.15	1.12	1.05	1.12	1.10	1.09
Kennebec	1.02	1.02	1.07	1.05	1.20	1.02	1.07
Yampa	1.00	1.10	1.00	1.02	1.00	1.00	1.02
Sebago	1.17	1.10	1.35	1.15	1.07	1.12	1.16
Mean	1.05	1.09	1.14	1.07	1.10	1.06	

[1] Index of discoloration computed by adding products of number of tubers in each class multiplied by numerical value for the class and then dividing by total number of discolored tubers. (1=slight discoloration; 2=moderate; and 3=severe.)

	1949		1950	
Least significant difference:	.05	.01	.05	.01
Between variety means	.09	.12	.05	.07
Between treatments within varieties	.22	....	.14	.18
Between varieties within treatments	.27	....	.13	.17

may be caused by the fact that the plants were younger than they were at the time of application of a comparable treatment in 1949, but the difference in age was only 10 days. However, the fact that Sebago showed a slight though non-significant increase in yield with 2,4-D application both years indicates that varietal response as well as physiological age of plants might be involved. It does not rule out the possibility that for a given variety there may be a critical stage of growth at which the plant is susceptible to injury. It is possible that treatment before or after such a critical stage will result in only minor injury.

The influence of vine killing on specific gravity of tubers depends to a great extent upon variety and season. The greatest reduction in

tuber density was observed in late varieties in 1950, although Cobbler, the earliest of four varieties tested, showed statistically significant reduction in tuber density with early killing. Since Cobbler did not show appreciable increases in yield even after the early killing dates, it is evident that tubers will continue to increase in starch content even after vines become senescent and tubers cease to make important gains in size. It was also noted that specific gravity of tubers from chemically killed plots of Kennebec and Sebago was higher than that of tubers from mechanically killed plots of those varieties in 1950. There was no such difference between methods in 1949. This can be attributed to the slow killing action of the chemical spray in 1950 compared with the previous year. These results agree with those of McGoldrick (16) and McGoldrick and Smith (17), who found higher specific gravity in tubers from plots where the killing action of various chemicals was relatively slow.

The data on specific gravity emphasize the need for establishing the magnitude of differences that are needed to be of practical importance. In these experiments it was possible to measure statistical significance between means that differed as little as .001 when based on 16 or 24 determinations as in the case of over-all treatment and variety means. Differences as small as .003 were significant when means were based on four determinations, as was the case with treatments within a given variety or for variety means within the same treatment. It is doubtful whether differences as small as .003 in specific gravity can be detected in the quality of the cooked product. Reductions in specific gravity as high as .012 and .013 resulted from early (August 21) killing of Kennebec and Sebago in 1950. These differences are great enough to be detected readily in the cooked potatoes. Despite rather rapid increases in specific gravity that might occur late in the growing season, it is evident that yield is much more important than cooking quality in determining vine killing practices. After yields have ceased to increase rapidly and the vines approach senescence there may still be gains in specific gravity that are of statistical but not practical significance.

The important influence of climatic factors on specific gravity is evident in the higher values observed in 1950 compared with 1949 and in the change in position among the varieties. Kennebec tubers from check plots were significantly lower in specific gravity than Cobbler in 1949 and significantly higher in 1950. When changes of this type occur with seasons, it is difficult to make accurate generalizations with regard to relative quality of varieties. It would appear that changes due to climatic factors which vary from season to season or location to location are often of greater magnitude than inherent differences among the common varieties.

Vascular discoloration was much more prevalent under conditions of high temperature and low moisture supply such as prevailed at Clear Lake, Iowa, in 1949. More discoloration resulting from fast killing compared with slow has been reported by Hoyman (10), Eastman (6), Callbeck (2), McLachlan and Richardson (14), Meadows (15), Rich (25, 26), McGoldrick (16), and Cunningham *et al.* (4). The results reported here are in agreement with their observations since chemical killing was accomplished much more rapidly in 1949 than in 1950. The greater speed might be attributed to weather conditions prevailing at time of application or to

the physiological condition of plants resulting from high temperatures and low rainfall preceding application. In 1949 the temperature on August 26 when the first killing treatments were applied was 91°F. The average maximum temperature for the ten preceding days was 84.7°, having exceeded 90° on three of these days. Precipitation totaled .01 inch during the two weeks preceding treatment. The following year the first treatment was applied on August 21, when the temperature was 68°. During the ten days preceding treatment the average maximum temperature was 70.3°, having exceeded 80° on only three of them. Precipitation during the two weeks preceding treatment was 1.67 inches. For late killing there was very little difference in weather conditions and moisture supply. The average maximum temperatures for the ten days preceding late treatment were 71.2° in 1949 and 74.8° in 1950. Precipitation during the two weeks prior to treatment was 2.3 inches in 1949 and .52 inch during the comparable period in 1950. In the case of the late treatment the greater discoloration could not be attributed to weather conditions at and immediately preceding treatment. However, the plants were more nearly mature at the time of the second killing treatment in 1949 than they were in 1950. The second killing treatment was applied 127 days after planting in 1949 and 102 days after planting in 1950. Hot, dry weather as shown in table 2, had prevailed during most of the growing season up to the later vine killing date in 1949. It is unfortunate that soil moisture supplies were not determined during the course of these experiments. Without such data it can only be assumed, on the basis of weather data, that the moisture supply to the crop was much lower during the growing season in 1949 than it was in 1950.

In contrast to results reported by Eastman (6), Callbeck (2), McGoldrick (16), and Meadows (15), who found more vascular discoloration in tubers from plants killed near maturity, the results at Clear Lake, Iowa, in 1949 showed slightly less discoloration after late killing than after early. Hoyman (10) also observed that the amount of vascular discoloration was less when applications were made later in the season. Without data on temperature, soil moisture, and other conditions, it is difficult to find reasons for these apparent discrepancies. However, if potatoes are more susceptible to discoloration as they near maturity, failure to show this phenomenon in the 1949 experiment in Iowa might be due to rather severe drought conditions that prevailed at the time of early killing. Such conditions probably increased the rate of kill and consequent vascular discoloration to such a degree that it was equal to that caused by killing when the plants were more mature, the temperatures relatively lower and there had been 2.3 inches of rainfall.

With the data at hand it is difficult to isolate the effects of different environmental factors on the occurrence and severity of vascular discoloration following vine killing. Apparently, this type of discoloration is increased by conditions such as high temperatures, limited rainfall or a combination of the two which make moisture a limiting factor. A fast rate of kill alone is not responsible for increased discoloration, because in 1950 with below normal temperatures and ample rainfall, the mechanical removal of vines did not cause an increase in amount or severity of vascular discoloration.

Summary

Chemical and mechanical vine killing and a summer application of 2,4-D were tested in 1949 and 1950 on four varieties of potatoes grown in muck soil at Clear Lake, Iowa.

The two seasons provided contrasting climatic conditions, but both were rather sharp departures from normal. In 1949 temperatures were generally above normal, with below normal rainfall in August and September, whereas 1950 had temperatures below normal and precipitation near or above normal during most of the growing season. Data showing these differences in weather conditions are presented.

Yields and specific gravity were generally higher in 1950 than in 1949, the lower temperatures and more ample moisture supply in 1950 acting to the advantage of the late varieties.

Potato tubers will increase in specific gravity after vines have begun to show symptoms of senescence and after yield has ceased to increase appreciably. The increase in starch content after this stage, however, is probably too small to be of any practical importance; therefore yield is a more important consideration in determining the best vine killing practice.

Vascular discoloration was more prevalent in 1949 than it was in 1950. This defect was increased significantly in 1949 by both chemical and mechanical killing with slightly more discoloration following early compared with late killing. In 1950 vine killing did not increase the incidence of vascular discoloration.

Response to 2,4-D was much more rapid and symptoms of injury to the plants were more severe in 1949 than in 1950. Vine maturity was hastened 10 to 14 days the first year, but earlier maturity due to the 2,4-D spray was not noticeable in 1950. It would be difficult to accomplish the purpose of vine killing by hastening plant maturity with 2,4-D, because this effect is dependent on climatic factors as well as on variety and the physiological age of the plants at time of application.

The 2,4-D treatment did not produce any significant increases in specific gravity of tubers. In 1949 there was a trend toward lower tuber density in Cobbler and Sebago following the 2,4-D treatment.

With the data available it is difficult to isolate the effects of temperature and soil moisture, but it seems that a combination of conditions which result in a deficient moisture supply is responsible for at least some of the results observed in these experiments. Results which accompanied high temperature and low rainfall conditions in 1949 were lower yields, lower specific gravity of tubers, more rapid kill with chemical treatment, earlier vine maturity following 2,4-D application, and an increase in severity of vascular discoloration following vine destruction.

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A NEW SPROUT INHIBITOR FOR POTATO TUBERS[1]

PAUL C. MARTH[2] AND E. S. SCHULTZ[3]

During experiments on the sprout-inhibiting effects of a variety of chemicals on table stock potato tubers, it was found that 3-chloro-isopropyl-N-phenyl carbamate (3-Cl-IPC)[4] was extremely effective in preventing sprout growth when compared with some other sprout-inhibiting chemicals. Of further interest is the fact that Anderson, Linder and Mitchell (1) have found that this and some related carbamates evaporate very rapidly when small amounts are exposed to room temperatures, apparently no appreciable amount of the chemical being left on the treated surface. This characteristic may be of interest from a toxicological standpoint.

EXPERIMENTAL PROCEDURES AND RESULTS IN MARYLAND

In England, Rhodes *et al.* (6) reported that isopropyl-N-phenyl carbamate (IPC) markedly reduced sprouting of stored potato tubers and that it was superior to the methyl ester of naphthaleneacetic acid (MENA) for this purpose.

Preliminary experiments on stored potato tubers started in December 1950 at the Plant Industry Station, Beltsville, Maryland, however, indicated that under certain conditions 3-Cl-IPC may be even more effective as a sprout inhibitor than the parent carbamate (IPC). In one of these experiments, IPC, 3-Cl-IPC, MENA, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and maleic hydrazide were applied separately as dusts of 1 per cent concentration in talc. Individual 10-pound lots of unsprouted Katahdin potatoes that had been stored at 40° to 50°F. for approximately 3 months were treated with each mixture on December 6; four lots were used per treatment and four untreated lots served as controls. Immediately after treatment, all lots were placed in paper bags, sealed and then stored for 2 months in a room having an air temperature range of 40° to 50°F. After storage, the various lots were placed in a room where temperatures of 70° to 75°F. were maintained. The potatoes were examined for sprout development at intervals thereafter. The bags were resealed after each examination.

Under the conditions of this experiment, 3-Cl-IPC proved to be the most effective chemical used. Tubers treated with this compound remained dormant and relatively firm for 4 months in a room where the air temperatures ranged from 70° to 75°F. Tubers treated with IPC, 2,4,5-T or MENA remained dormant for 1 month at these temperatures but later started to develop short knobby sprouts. Maleic hydrazide was entirely ineffective in these tests, confirming the results of Marshall and Smith (3) when they applied this chemical to surfaces of the tubers. The average fresh weights (grams) of sprouts per tuber developed during 4 months at 70° to 75°F. were 8.4, 8.2, 5.1, 3.9, 3.6 and 0, respectively, for the

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[2] Physiologist and [3] Principal Pathologist, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Beltsville, Md.

[4] 3-Chloro-isopropyl-N-phenyl carbamate was furnished for these studies by Pittsburgh Plate Glass Company, Columbia Chemical Division, Pittsburgh, Pennsylvania, and by U. S. Industrial Chemicals Company, Incorporated, Baltimore, Md. The butyl ester of 2,4,5-T was supplied by the American Chemical Paint Company, Ambler, Pa.

control, maleic hydrazide, 2,4,5-T, MENA, IPC and 3-Cl-IPC treatments. Shriveling was most severe in the sprouted control lots of tubers and less so in treated lots which had fewer sprouts.

An experiment was undertaken in December 1951 to determine how quickly Katahdin tubers took up sufficient 3-Cl-IPC to cause dormancy when exposed to temperatures of 70° to 75°F. Individual lots of 10 uniform-sized tubers that had been shipped from Maine and stored at 40° to 50°F. for approximately 3 months were dipped in water suspensions of 0, 0.1, 0.5 or 1 per cent concentration. Following treatment with the chemical at different concentration levels, separate lots were held in ventilated baskets at 70° to 75°F. for 0 hour (immediate storage), 3 hours, 7 hours, 3 days, 7 days and 14 days before they were placed in 40° to 50°F. storage. Each chemical treatment was replicated twice for each of the 6 different time periods selected. For comparison, similar lots of untreated tubers were kept out of storage. At the end of 55 days from the beginning of the experiment, the tubers were removed from low-temperature storage and returned to the higher temperature (70° to 75°F.) for 2 weeks.

At low concentration 3-Cl-IPC lost its effectiveness very rapidly when the treated tubers were held at a warm temperature (Table 1). For instance, at 0.5 per cent concentration the chemical was completely effective only on tubers stored at the low temperature immediately after treatment. At this dosage, 20 per cent of the effectiveness of the chemical was dissipated within 3 hours at high temperature (70° to 75°F.). Tubers that were treated at the 1 per cent level, however, and held for as long as 14 days in a warm room retained sufficient chemical to cause complete inhibition of bud growth.

In order to develop a more effective method of using 3-Cl-IPC, dormant unsprouted Katahdin potato tubers were dipped in water suspensions containing 0.1, 0.25, 0.5 or 1 per cent concentration and immediately sealed in single-thickness Kraft paper bags on December 7, 1951. Two separate lots consisting of 16 tubers each for each treatment, along with two untreated lots, were placed in storage at 40° to 50°F. and similarly treated and untreated lots were placed at 70° to 75°F. The sealed bags of tubers were removed from the lower to the higher temperature after 57 days. Sprouting data were obtained after all lots had been kept for at least 2 weeks at 70° to 75°F.

Of the tubers stored continuously at the high temperatures for 71 days, those treated with 1 per cent 3-Cl-IPC remained completely dormant. Ten per cent of the tubers that had been dipped at the 0.5 per cent concentration were sprouted. Both the 0.1 and the 0.25 per cent concentrations were ineffective in preventing sprouting and the treated tubers were badly shriveled.

On tubers placed in low-temperature storage immediately after treatment, concentrations of 0.25, 0.5 and 1 per cent of 3-Cl-IPC were effective in preventing sprouting after their transfer to the higher temperature. At the lowest dosage level (0.1 per cent) the chemical was ineffective.

Tubers bruised in shipment before treatment with a dip containing 3-Cl-IPC at 1 per cent concentration developed a slightly more intense browning than did bruises on the controls. This effect was not apparent when smaller amounts of the chemical were applied. Losses from decay were negligible in all lots.

TABLE 1.—*Effect of 3-Cl-IPC on sprout development on Katahdin potato tubers treated and held at 70° to 75°F. for various periods prior to storage at 40° to 50°F.*

(Twenty tuber samples were treated on December 7 and kept at 70° to 75°F. or stored at 40° to 50°F. or both for 55 days. Data were obtained after the tubers had been held after storage for an additional 2 weeks at 70° to 75°F. to permit sprouting.)

Dip Concentration of 3-Cl-IPC	Percentage of tubers with sprout growth ¼ to ½ inch long when held at 70° to 75°F. for indicated period before storage					
	0 Hour	3 Hours	7 Hours	3 Days	7 Days	14 Days
Control	100	100	100	100	100	100
0.25 Per cent	60	100	100	100	100	100
0.5 Per cent	0	20	40	40	100	100
1.0 Per cent	0	0	0	0	0	0

Throughout the experiments with 3-Cl-IPC it was noted that apical dominance was reduced in those treatments that did not effectively control sprouting. In one experiment, for instance, the number of eyes from which sprouts developed was found to average 3.8 per tuber for the controls and 6 per tuber for the treated lots. Sprouts on the treated tubers were distributed over the entire tuber.

In a preliminary field experiment in which 3-Cl-IPC was used as a spray on the tops of potato plants this compound was not effective in retarding sprout development of the tubers. Apparently it was not absorbed or translocated as is the case with 2,4,5-T and maleic hydrazide (2, 5). On July 17, at Beltsville, Maryland, 4 plots of 10 hills each of vigorously growing Katahdin potatoes were sprayed with a water mixture containing 0, 0.06, 0.1 or 0.25 per cent concentration of 3-Cl-IPC. Tween-20 at 0.5 per cent concentration was used as a dispersing agent.

In comparison with the control plots, 3-Cl-IPC did not cause noticeable effects on the vines at any of the concentration levels employed. The tubers were harvested on August 1 and stored at 40° to 50° F. for 90 days. Upon removal from storage to the higher temperatures (70° to 75°F.) tubers in the controls as well as in all the treated lots, started sprouting profusely and evenly. Since the spray treatments were applied at the prevailing air temperatures of 85° to 90°F., it seems quite likely that much of the applied chemical may have evaporated soon after it was deposited and that the quantity which remained was not translocated into the tubers in sufficient amounts to affect sprout development.

EXPERIMENTS WITH POTATO TUBERS ON WASTE PILES IN MAINE

Experience has shown that potato waste or dump piles are a primary source of spores that cause late blight infection. Sprouts contract late blight from infected tubers deposited on dump piles; from infected sprouts of these tubers the late blight spores are blown to potato tops in commercial fields as soon as the plants are up and before the fields are sprayed.

To facilitate control of late blight development on dump piles, sprout

inhibitors were used experimentally in Maine in 1950 (4), when it was found that 2,4,5-T butyl ester prevented sprout development as well as stopped growth of sprouts that had been formed before treatment.

In 1951 butyl ester of 2,4,5-T and 3-Cl-IPC were used on potato waste piles. Water suspensions containing 0.25 per cent of 2,4,5-T or 0.5 or 1 per cent concentration of 3-Cl-IPC were sprayed on each layer of tubers as they were deposited on the piles. A gallon of one mixture or the other was used for spraying 360 pounds of tubers. The tubers represented mixed varieties (Chippewa, Green Mountain, Mohawk and Teton)

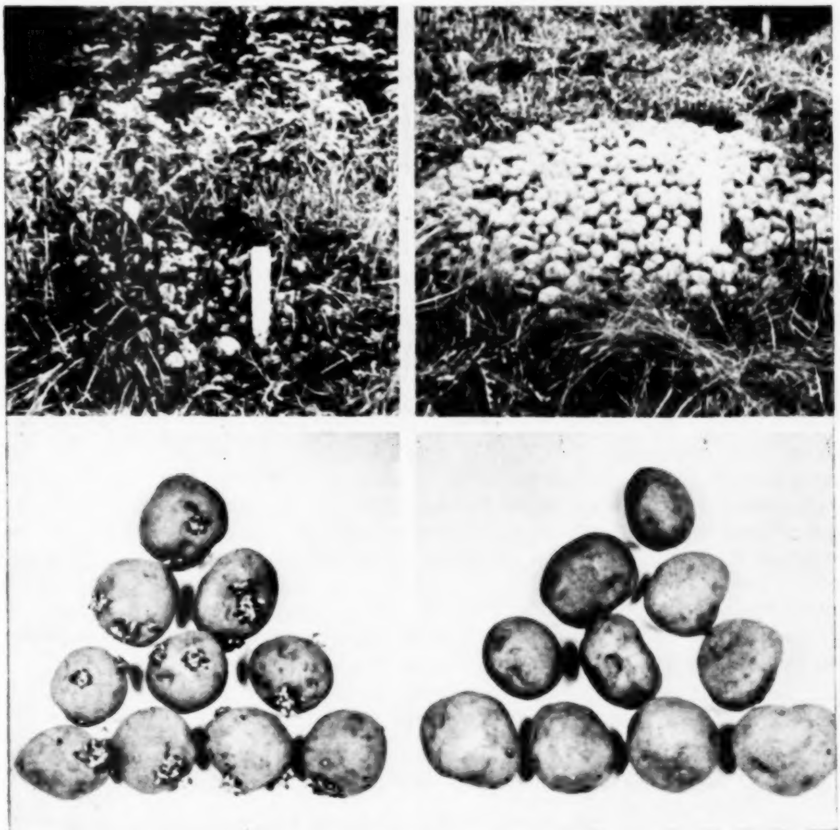

Figure 1.—Upper left, potato waste pile not sprayed with dormancy-inducing chemical. Tall potato tops developed; some plants were infected and killed by late blight fungus. Upper right, *treated*: potato waste pile sprayed with 1 per cent 3-Cl-IPC on May 26, free from sprouts on September 2, when both the untreated and the treated piles were photographed.

Lower left, untreated Katahdin table stock potatoes showing sprout development when held for 2 weeks at room temperature (70° to 75°F.) after removal from storage. Lower right, comparable potatoes treated with a water dip containing 0.5 per cent 3-Cl-IPC and stored immediately after treatment on December 7. Both lots were removed from storage after 55 days and held for 2 weeks at 70° to 75°F. prior to taking of photograph on February 14.

that had formed 2- to 3-inch sprouts before treatment on May 26. Five piles of tubers were treated while 3 piles served as untreated controls.

Observations from June to September on the treated tubers disclosed that all treatments had prevented formation of sprouts as well as inhibited further growth of the sprouts that had developed before the tubers were treated (Figure 1). The tubers in the untreated controls developed 20- to 30-inch plants that contracted late blight during the season (Figure 1).

These results show that treatments with 0.5 to 1 per cent spray concentrations of 3-Cl-IPC effectively control sprouting on potato waste piles and so facilitate disposal of waste potatoes and control of late blight on potato dump piles.

Discussion and Summary

In the present experiments 3-Cl-IPC has proved to be a very potent sprout inhibitor when applied to stored potato tubers. The conditions under which the chemical is applied strongly influence the inhibiting response. The effective treatment with 3-Cl-IPC was a water dip containing 1 per cent of the chemical. Only one-half as much of this chemical was required when the tubers were stored at low temperatures (40° to 50°F.) for about a month prior to storage at room temperatures (70° to 75°F.). A lower concentration (0.25 per cent) was effective only when the treated tubers were sealed in paper bags and stored for about one month or longer at the low temperatures before they were placed in the warm room.

The fact that 3-Cl-IPC apparently evaporated from a treated surface rather readily at ordinary room temperature (1) makes it of additional interest from the standpoint of chemical treatment of food products, for there is a possibility that only a small amount of residue would be left on the surface of potatoes or other plants to which this compound might be applied. It is also of interest that under the prevailing summer weather conditions in Maine, where the average temperatures are somewhat cooler than at Beltsville, 3-Cl-IPC effectively controlled sprouting in cull piles.

Caution: Since data on the effects of repeated dosages of small quantities of 3-Cl-IPC and IPC on animals and humans are lacking at present, these chemicals are not recommended or endorsed for applications to potatoes to be used for food.

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FACTORS AFFECTING THE DETERMINATION OF SURFACE COLOR OF PEELED POTATOES[1]

KARLA LONGREE[2]

An important quality factor of potatoes is their whiteness when they reach the table. The problem of potato discoloration has become increasingly serious. Persons engaged in institution food service, in particular, are concerned over a type of potato discoloration which appears on some tubers peeled in a mechanical peeler while they are held in water prior to being cooked. The entire surface may turn pink within a short time after peeling and the pink may change to various hues of red during the next four to six hours. After a day's immersion in water the tubers may appear purplish grey. The discoloration deepens to various hues of brownish black after cooking.

Preliminary to a study on the effect of kitchen practices and peeling equipment on surface discoloration of potatoes prepared in quantity, experiments were conducted to find out what conditions, other than those investigated in the main study, would have an effect on discoloration and if not controlled might invalidate results.

From observations made and color determinations performed it was found that, aside from varietal color characteristics and discolorations caused by diseases and insect injury, other factors may have an effect on surface color of cooked potatoes. Precautions which must be exercised in the selection and preparation of samples are discussed below.

As with other foods (3), color measurements on potatoes may well become an important tool in quality control.

The purpose of this paper is to share with others the information on the factors that may affect color readings on potatoes.

MATERIALS AND METHODS

Unless stated otherwise, the potatoes used in the tests were grown in the same field, harvested at the same time by hand, and handled carefully to avoid pre-bruising. They were of the Ontario variety. Tubers of this variety are liable to discolor more or less severely following peeling in mechanical peelers.

Although observations were made of color of uncooked tubers, all color measurements were made on the tubers after they had been cooked. The instrument used for color determination was the Hunter Color Difference Meter (1, 2). With this instrument, color is measured directly by reflectance. Readings were taken for lightness (Rd); redness (+a) or greenness (—a); and yellowness (+b) or blueness (—b). Increase in Rd value indicates greater lightness. The apparatus compares unknown specimens with a standard panel of predetermined color characteristics. The panel used here has the values: Rd: 39.0; a: —1.1; b: —3.3.

TURGIDITY

Occasionally it had been observed in the kitchen that the less firm tubers of a lot became more severely discolored than the turgid ones. To test the effect of flaccidity on surface color, tubers that had been

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[2] New York State College of Home Economics, Ithaca, N. Y.

stored at 38° to 40°F. for three months, were sorted for firmness. The cause for the flaccid state of some of the tubers was not known. A number of the flaccid tubers were examined for disease or blackspot, and were found free from these defects. There was no sprouting in these tubers but they were more thinly skinned than the turgid ones. Two samples from both the turgid and flaccid lots were machine peeled and allowed to stand in water for six hours. After cooking, the color factors of the two sub-samples from each sample were measured. The flaccid tubers were discolored more severely than were the turgid ones (Table 1).

TABLE 1.—*Surface color of firm and flaccid tubers of same origin after three months of storage at 38° to 40°F.*

Firmness of Tubers	Test	Color Factors		
		Reflectance Rd[1]	Redness —a[1]	Yellowness +b[1]
Firm	1	43.5	3.1	21.1
	1	41.3	2.9	20.6
Flaccid	2	34.9	2.1	13.7
	2	31.2	1.8	14.5

[1]Each figure represents an average of four readings taken on two samples of mashed surface tissue.

Tubers of several varieties were tested for color after a brief period of storage and again in early spring. The tubers gave different color readings after the varying lengths of time in storage. Details of this investigation will be presented in a later publication.

LABORATORY STORAGE OF TUBERS PRIOR TO PEELING

No observations were made on tubers immediately after removal from cold storage. The following comparison was made of three 10-pound lots of tubers: one lot was held in a dark room at 72° to 76°F. for three hours; the second lot was held under the same conditions for three days; and the third was held in a dark room at 89° to 91°F. for three days. It was found that after peeling and before cooking the tubers held at the higher temperature were more severely discolored than the remaining two lots, which were similar.

PEELING

Hand vs. Machine Peeling. It was found that, in general, the method of peeling and type of equipment used had a very great effect on surface color of potatoes. Details of this investigation will be reported in a later publication.

Length of Peeling Time and Depth to Which Tubers Are Peeled. The deeper the peeling the more of the outside tissue is removed. Since the color of the different tissues of the tuber may vary, the extent of removal of outer tissues may affect color readings. Also with longer peeling time necessary for deeper peeling, the tubers will be tossed for a longer time;

this will be a factor of importance in tubers that are sensitive to bruising. On the other hand ,peeling to a great depth may remove tissues most sensitive to bruising.

Load of Potatoes Peeled at One Time in Peeler. In certain peelers, the load of potatoes peeled at one time may affect the degree to which the tubers are thrown and bruised.

Conditions of Holding Peeled Tubers in Water before Cooking. Observations were made on the effect of holding tubers under cold running water and on tubers held, at a comparable temperature, in non-running water. Greater discoloration was found in the tubers held under running water.

Size and Shape of Container in Which Peeled Tubers Are Held before Cooking. When non-running water was used, with sample weight identical and with depth of covering water being shallow and the same for all samples, lots held in shallow containers had a high percentage of tubers discolored, whereas the lots held in relatively deep and narrow containers revealed only a small percentage of the tubers discolored.

Depth of Water Covering Tubers. To test the effect of coverage on intensity of discoloration samples of 240 gram, 500 gram and 720 gram-weight were prepared. The depths of coverage varied from 1 inch to 4 inches. It was observed that, in general, tubers covered by 1 inch of water were more intensely discolored than those covered 4 inches deep. The intensity of discoloration was most severe in the small samples covered by a shallow layer of water and least severe in the small samples covered by a large amount of water (Table 2).

Position of Cut Pieces. If tubers are halved or quartered immediately after machine peeling and are held before cooking, a system of placing the pieces in the container may be essential for obtaining comparable color readings. For example, in a sample of halved tubers, the halves with the cut portion turned toward the surface of the covering water revealed color values entirely different from the halves with the outer portion turned up.

Length of Holding Time and Temperature at Which Peeled Tubers are Held. Observations and some objective color determinations were made on potatoes held at different temperatures following machine peeling. In one test, observations were made at frequent intervals on halved tubers held at room temperature and in the refrigerator after peeling. After four hours the potatoes were cooked and color measurements taken (Table 3, Test 1). Up to four hours of holding, discoloration was more pronounced

TABLE 2.—*Effect of depth of water coverage on intensity of discoloration of tubers held for 24 hours following peeling.*

Weight of Sample Grams	Relative Intensity of Discoloration[1] Depth of Coverage 1"	Depth of Coverage 4"
240	xxxxx	xx
500	xxxx	xxx
720	xxxx	xxx

[1]x Indicates faint pink.
xxxxx Indicates purplish red.

in tubers that were held at room temperature.

In other tests, some of the tubers were held at room temperature and some in the refrigerator for 6 hours. Color determinations were made on one-half of the lots held at the two temperatures. The second half of the lot held at room temperature was then moved to the refrigerator, held for an additional 18 hours, cooked, and tested for color. It was found (Table 3, Test 2) that after 6 hours of holding, the color readings of tubers held at room temperature were very familiar to those of tubers held for the same length of time in the refrigerator.

The length of time of holding in water may indirectly affect color readings because of textural changes that may occur with prolonged soaking. It was found that with increased soaking time the outer tissues of the tubers became hardened. This hardness interfered with proper mashing and mixing of cooked tissues and resulted in a mixture less homogeneous than is desirable for exact and comparable color determinations.

TABLE 3.—*Effect on surface color of length of holding time and of temperature at which tubers were held after peeling.*

Temperature	Length of Holding Time	Number of Replicates		Color Factors[1]		
				Reflectance Rd	Redness —a	Yellowness +b
	Hours	Lot				
Refrigerator	4	1	1	40.5	3.3	10.1
Room	4		1	47.3	3.4	14.0
Refrigerator	6	2	4	29.3	2.5	12.2
Room	6		4	29.4	2.5	11.7
Refrigerator	24		4	29.5	2.6	12.0
Room for 6 hours, then refrigerator for 18 hours	24		4	29.0	2.5	11.8

[1]The measurements were made on patties of mashed surface tissue.

Cooking Method

The method of cooking potatoes might be a factor in surface color of potatoes because of water absorption. Furthermore, the method of holding after cooking, which affects release of steam and drying, might also have an influence on surface color.

Removal of Sample Tissue

When removal of surface tissue is desirable for color determination, the depth to which the outer cell layers are removed may affect color values, especially in cases where the outer layers are very different from the underlying tissues. If a thin layer is removed, the chance of "diluting" color will be reduced. Uniform slicing is also important in order to avoid faulty and variable color readings.

Quick mashing and mixing while the slices are still hot is essential for obtaining a homogeneous mixture.

When color determinations were made on the Hunter Color Difference Meter it was found that when samples were warmer than room temperature variable readings were obtained.

COLOR DETERMINATIONS ON SLICES *vs.* MASHED TISSUE

In some tests, the outer portion of the tubers of five different lots was removed in thin slices which were then laid side by side. In other tests, the slices were mashed together and the mashed tissue shaped into patties of definite diameter and thickness. Variability of the first type of samples was tested by rearranging the same slices twice between color readings Table 4). In the second type of sample, the patties were compared with each other (Table 5). In the samples composed of slices, readings varied considerably. In contrast, when the surface tissues of all tubers involved in a given sample were mashed and mixed together less variable readings were obtained.

TABLE 4.—*Range of color readings taken three consecutive times on slices cut from surface of tuber; the slices were rearranged between the readings.*

Sample Number	Range of Readings		
	Reflectance Rd	Redness —a	Yellowness +b
1	20.3 to 25.7	1.3 to 2.0	11.6 to 13.8
2	31.6 to 35.8	3.0 to 3.6	16.1 to 19.1
3	21.4 to 24.5	2.3 to 2.7	10.0 to 14.1
4	33.1 to 37.6	2.4 to 3.8	13.3 to 16.6
5	34.9 to 39.4	3.1 to 3.4	11.9 to 15.9

TABLE 5.—*Range of color readings taken on mashed slices removed from surface of several tubers; the mashed tissue was shaped into two patties of uniform size. Readings were taken on both sides of each patty.*

Sample Number	Range of Readings		
	Reflectance Rd	Redness —a	Yellowness +b
1	28.8 to 29.5	1.4 to 1.5	11.6 to 13.1
2	44.1 to 45.6	3.0	18.4 to 18.7
3	34.1 to 35.5	2.0 to 2.1	13.9 to 14.4
4	37.0 to 38.3	2.3 to 2.4	17.1 to 17.6
5	31.6 to 32.0	1.5 to 1.8	15.2

SUMMARY AND RECOMMENDATIONS

Preliminary to an investigation on the effect of kitchen practices and peeling equipment on surface discoloration of potatoes prepared in quantity, a study was made to find out which factors other than those investigated in the main study might affect determination of surface color of cooked tubers. The Hunter Color Difference Meter was used. On the basis of observations made in this study it is recommended that when surface color of potato is to be determined the following factors should be taken into consideration: turgidity of tubers; length of cold storage; temperatures during period of holding unpeeled tubers prior to peeling; method and depth of peeling, and, if mechanical peeler is used, the load

peeled at one time; length of time and conditions of holding peeled tubers in water before cooking; cooking method; and method of removing and treating tissues to be used for color determination.

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